

antenna elements similar to antenna elements 30 in smart antenna array 28. In the embodiment shown in FIG. 1, antenna unit 18 is located on an antenna tower 22. However, antenna unit 18 may be otherwise located, for example on a building. Preferably, signals directed to and from antenna unit 18 are generally unobstructed near antenna unit 18, or in other words, antenna elements 30 can “see” a large area.

[0048] Traditional sector antennas used in cellular communication systems transmit radio signals in a wide beam to a relatively wide area, or sector, since the location of mobile stations is unknown to the system. Such systems pollute the electromagnetic environment by transmitting signals in unnecessary directions. In contrast, smart antenna system 14 divides the wide beam into a plurality of narrow beams. For example, in the embodiment shown in FIG. 1, smart antenna system 14 divides a wide beam 32 covering an approximate 120 degree range into seven narrow beams 34. This is accomplished by manipulating the phase of the signals received by antenna elements 30 of smart antenna array 28. In some embodiments, narrow beams 34 are formed using a beamforming network, sometimes referred to as a BFN. In contrast, sector antenna 31 transmits and receives signals throughout the sector through wide beam 32, bypassing the beamforming network. Signals may be communicated between antenna unit 18 and a particular mobile station 15 via a narrow beam 34 or via wide beam 32 (using sector antenna 31), depending on various parameters.

[0049] Antenna unit 18 may be coupled to smart antenna apparatus 16 by one or more radio signal wires 40 operable to communicate radio signals between antenna unit 18 and smart antenna apparatus 16. For example, antenna unit 18 may be coupled to smart antenna apparatus 16 by a plurality of radio signal wires 40, each corresponding to a narrow beam 34. Similarly, smart antenna apparatus 16 may be coupled to base station transceiver 24 by one or more radio signal wires 42 operable to communicate radio signals between smart antenna apparatus 16 and base station transceiver 24. Radio signal wires 40 and 42 may include any wire media suitable for communicating radio frequency signals. For example, in one embodiment, radio signal wires 40 and 42 are radio frequency (RF) cables.

[0050] When a mobile station 15 transmits uplink signals, the uplink signals may be received along any number of narrow beams 34 due to multi-path or other interference phenomena, and/or due to overlapping areas covered by adjacent narrow beams 34. The uplink signals received via each narrow beam 34 are communicated to smart antenna apparatus 16 via radio signal wires 40. In one embodiment, one or more separate radio signal wires 40 are provided to communicate the signals received via each narrow beam 34.

[0051] Smart antenna apparatus 16 processes uplink signals received along each narrow beam 34 and/or other input signals or data to select the best narrow beam 34 and to allow uplink signals received via that narrow beam 34 to be communicated to base station transceiver 24 via radio signal wires 42. For example, smart antenna apparatus 16 may select the best narrow beam 34 based on one or more inputs or parameters. One input may include signaling information received by signaling information monitoring system 106 (described below in connection with FIG. 2). Other example inputs or parameters include signal strength, signal quality, relevant power, and signal history of signals received from

one or more mobile stations 15. After smart antenna apparatus 16 communicates the uplink signals received via the selected narrow beam 34 to base station transceiver 24, the uplink signals may be processed and/or further communicated by base station system 12. It should be noted that the term “narrow beam” as used in this document applies both to the physical beams through which antenna unit 18 transmits and receives signals (as indicated using reference numeral 34 in FIG. 1) as well as the signals received via each of the physical beams.

[0052] When downlink signals are to be transmitted from base station system 12 to mobile station 15, the downlink signals are communicated from base station transceiver 24 to smart antenna apparatus 16 via radio signal wires 42. Smart antenna apparatus 16 may select a best narrow beam 34 through which to send the downlink signals. Like the beam selection for uplink signals discussed above, the beam selection for the downlink signals may be based on one or more inputs or parameters, including signaling information received by signaling information monitoring system 106. Other example inputs or parameters include signal strength, signal quality, and signal history of signals received from one or more mobile stations 15.

[0053] Smart antenna apparatus 16 may switch from one narrow beam 34 to another narrow beam 34 accordingly. For example, when mobile station 15 moves to a new location, smart antenna system 14 may switch from one narrow beam 34 to another narrow beam 34 for receiving uplink signals from and/or transmitting downlink signals to mobile station 15. In this manner, smart antenna system 14 may locate and track mobile stations 15 as they move within wide beam 32, and transmit signals to and receive signals from each mobile stations 15 via one or more appropriate narrow beams 34. At a particular point in time, the narrow beam 34 selected as the best beam for communicating uplink signals received from mobile station 15 to base station transceiver 24 may be the same as, or different from, the narrow beam 34 selected as the best beam for communicating downlink signals to mobile station 15. This may provide an advantage in situations in which the best beam for receiving uplink signals from a mobile station is not the same as the best beam for transmitting signals to that mobile station. This may be likely, for example, in high-interference environments, such as dense or urban environments.

[0054] Base station system 12 may communicate with mobile stations 15 within a range of frequencies, which may be divided into a number of frequency bands. According to some wireless communication standards, the available bandwidth is divided into a number of frequency bands, which may each be referred to simply as a frequency. In some standards, each uplink frequency (in other words, a frequency used for uplink communications) may be associated with a corresponding downlink frequency, such that pairs of frequencies are available. For example, in a P/E/R-GSM 900 environment, each frequency (both uplink and downlink) has a bandwidth of 200 kHz, and each uplink frequency band is offset from its corresponding downlink frequency band by 45 MHz. Typically, due to limitations of signal interference and cost, only a portion of the frequencies available in a particular environment are used by any particular base station transceiver. For example, in one embodiment, four pairs of uplink and downlink frequencies are to be used by each base station transceiver. It should be